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Title: **DYNAMIC MECHANICAL DEFORMATION OF A SiCp/Al-Li (8090) COMPOSITE**

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DYNAMIC MECHANICAL DEFORMATION OF A SiC_p/Al-Li (8090) COMPOSITE

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The deformation behavior in compression of a silicon carbide particle reinforced aluminum-lithium (8090) matrix composite, at strain rates in the range of 10^{-3} to 6500 s^{-1}, was investigated, and compared with that of unreinforced alloy samples. Dynamic strengthening in these composites was found to change depending on the direction of testing. These differences were attributed to differences in the orientation of the reinforcing particles.

1. INTRODUCTION

Characterization of the dynamic mechanical behavior of ceramic particle reinforced metal matrix composites is important if such materials are to be developed for structural applications. It is already well established [1] that the dynamic mechanical response of unreinforced metals and alloys can be significantly different at different strain rates. It is imperative therefore to study the dynamic mechanical response of such metal matrix based composites. This paper discusses such effects pertaining to an aluminum-lithium (8090) matrix based composite, reinforced with silicon carbide particles. These alloys and composites are being developed for aerospace applications because of their lower densities and superior mechanical properties as compared to conventional aluminum alloys and composites [2]. The effect of the fabrication and shaping process on the mechanical behavior is also discussed here.

2. EXPERIMENTAL PROCEDURE

Nominal composition (wt. %) of the alloy (8090) used in the present study is as follows: Al bulk, 2.2% Li, 1.1% Cu, 0.5% Mg, 0.12% Zr, 0.08% Fe, 0.04% Si. Both unreinforced and reinforced alloy containing 15 volume percent of silicon carbide particles were studied. The unreinforced alloy and composite samples were produced by a spray casting technique (OSPREY). These materials were obtained in the form of extruded billets. A schematic illustrating the extruded billet, and the corresponding test directions (A and C) is shown in Figure 1.

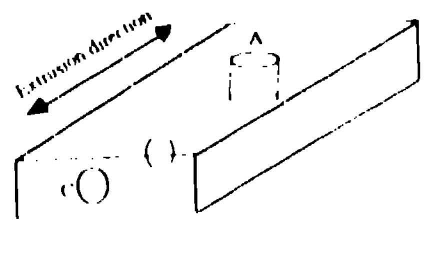

FIGURE 1

Schematic of the specimen orientations

Cylindrical specimens (0.5 cm x 0.5 cm) were machined out of the extruded stock material, in the two directions, for the static and dynamic tests. All of the samples were heated to 450°C for 8 hours, and furnace cooled prior to testing.

The static and dynamic mechanical responses of the unreinforced alloy and composite samples were measured in compression using a conventional screw driven testing machine, and a Split Hopkinson Pressure Bar respectively. All of the tests were performed at room temperature.

3. RESULTS AND DISCUSSION

Results of the mechanical tests for the unreinforced alloy and composite material have been compared in two different directions, and at two different strain rates in Figures 2 and 3 respectively. From the data for the unreinforced alloy, it is evident that the strain rate has a significant effect on not only the overall strength but also on the strain hardening coefficient. The strain hardening coefficient in a range of strain from 0.15 to 0.25 more than doubled, from 300 MPa per unit strain at a strain rate of 10^{-3} s^{-1} to 700 MPa per unit strain at 6500 s^{-1} strain rate. However, the orientation of the test axis with respect to the extrusion direction has no effect on the mechanical response of the unreinforced material.

The composite on the other hand, exhibits a moderate difference in the strength in the two tested directions (C versus A). For example at low strain rate and at strain of 0.3 the strength difference is 350 versus 320 MPa. At high strain rate and strain of 0.3 the difference is 550 versus 510 MPa. The yield stress for the composite samples is also expectedly larger than for the unreinforced alloy, especially so at higher strain rates. The strain hardening coefficients of the composite samples, at low and high strain rates are very similar to those of the unreinforced alloy samples tested at the same strain rates. This indicates that the reinforcing particles did not contribute to the strain hardening behavior of the matrix.

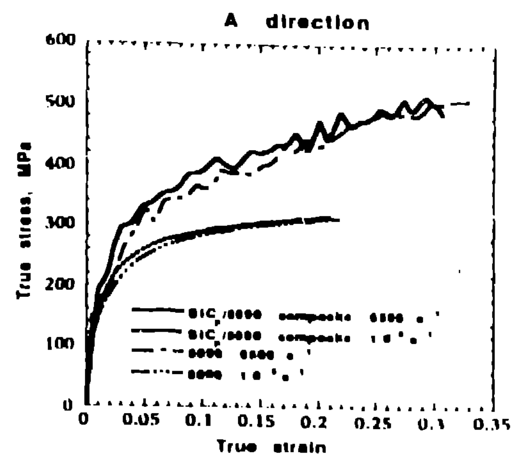

FIGURE 2

Stress strain response of the unreinforced alloy and composite in the A direction.

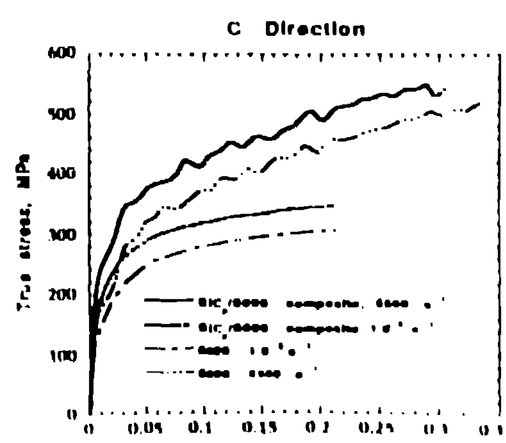

FIGURE 3

Stress strain response of the unreinforced alloy and composite in the C direction

The enhanced strain hardening behavior of the alloy is an effect of the lithium addition, since pure aluminum and many other aluminum alloys do not exhibit a significant strain rate effect below 10^{5} s^{-1} in the annealed condition. Lithium being an interstitial addition in aluminum, tends to diffuse to vacancies and dislocations and can hinder the motion of dislocations. The diffusion of lithium has been shown [2] to occur in aluminum alloys even at room temperature, and is a contributing factor to the strain rate sensitivity of this alloy. More important though, is the fact that dislocation accumulation occurs more rapidly at higher strain rates. The amount of dynamic recovery occuring at high strain rates is also smaller as compared to low strain rate testing. This leads to dislocation pileups and dislocation interactions and subsequently higher strain hardening.

The difference in the mechanical response of the composite in two different directions (C versus A) was perplexing at first, but was quickly resolved by optical microscopy. Optical micrographs taken perpendicular to the C and A directions of the composite are shown in Figures 4 and 5 respectively. From these micrographs it is evident that there is a significant anisotropy in the particle alignment in the C direction. The particles in that direction are aligned along the extrusion axis as a result of the extrusion process itself. Such alignment of the particles lends itself into producing a short fiber composite resulting in enhanced strength. On the other hand, the particles are more randomly distributed in the A direction.

The differences in the orientation of the reinforcing particles with respect to the loading axis, affect the deformation zones in the matrix surrounding the particles [3]. When the sample is loaded in the C direction, the constraint on the matrix surrounding the long side of the particles is greater than if the sample were to be loaded in the A direction (short side of particle). The larger constraint limits the initial plastic deformation to the short side of the reinforcing particles, which in turn leads to a larger dislocation pileup and subsequently higher strength. On the other hand, when loaded in the A direction, the matrix in the vicinity of the long side of the particles experiences little or no constraint, thereby deforming more uniformly. This may be the reason for the observed orientation effect in the composite and lack of it in the unreinforced alloy samples.

FIGURE 4

Optical micrograph (400 X) of the composite along the extrusion direction (C)

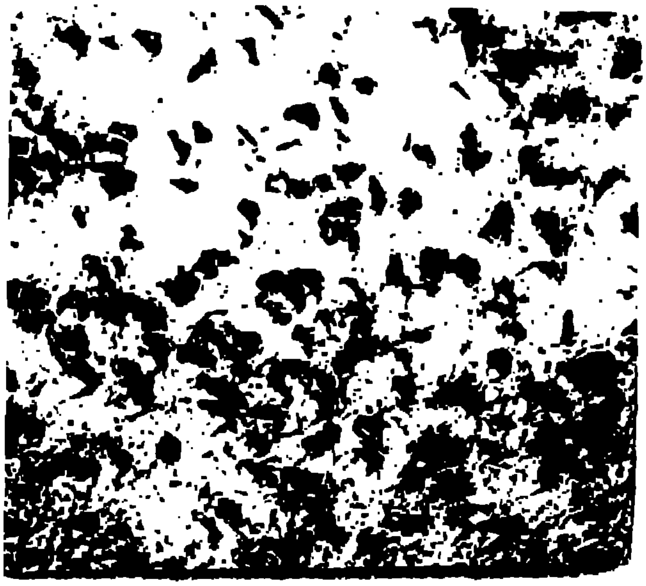

FIGURE 5
Optical micrograph (400 X) of the composite along the transverse direction (A)

An equation developed by Nardone and Prewo [4] predicts the enhancement in the yield strength of particle reinforced composites, as compared to the unreinforced alloy. Using this equation we calculate a theoretical value of 1.18 in the C direction and 1.05 in the A direction. The experimental values work out to be 1.09 and 1.02 respectively, which are in fairly good agreement with theoretical values. More importantly, the ratios of the strength for a range of plastic strains, of the composite to the unreinforced alloy, are equal. This further indicates that the reinforcing particles have no effect on the strain hardening response of the matrix.

4. CONCLUSIONS

The results presented are preliminary to the complete investigation of the anisotropy of this composite. We found that there is an particle orientation effect on the composite strength but that reinforcing particles have no effect on strain hardening of the matrix. It is also necessary to carry out an extensive statistical measurement to accurately quantify the effects of particle size, shape and orientation on the overall response of the composite. TEM work may also determine if some of the particle effects are being modified by the lithium additions.

ACKNOWLEDGMENTS

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